海洋プランクトン化石に記録された氷期南大洋の中層水形成

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Intermediate water formation in the glacial Southern Ocean inferred from marine plankton fossil record

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It is well known that the oceanic circulation in the Southern Ocean plays an important role in the global climate changes. For reconstruction of the past ocean circulation in the Southern Ocean, siliceous microfossils such as diatoms and radiolarians preserved abundantly in deep-sea sediments are widely used as paleoceanographic proxies. Fossil assemblages of diatoms (phytoplankton) indicate usually surface water environments, while radiolarians (zooplankton) can be used as indicator for not only surface but also intermediate and deep water conditions because of their discrete habitat depths for each species. In this study, quantitative analysis of radiolarians was conducted for two sediment cores COR-1bPC (54°S) from Conrad Rise and LHB-3PC (66°S) from off Lützow-Holm Bay in the Indian Ocean sector of the Southern Ocean. Past intermediate water formation in the examined area is discussed based on relative and absolute abundances of *Cycladophora davisiana*, which is an intermediate water species.

Relative abundance (%) of *C. davisiana* compared with the assemblage shows less than a few % during interglacial periods, while it reaches more than 60 % during glacial periods. Such high % of *C. davisiana* is recognized between 200 and 500 m of the water depth in the modern Sea of Okhotsk (Okhotsk Sea Intermediate Water), which is formed by advection of the brine rejection with sea-ice development at the northern shelf (e.g., Okazaki et al., 2004). Similarly, this species in the Japan Sea predominates in the assemblage from deeper than 1,000 m water depth corresponding to the well-ventilated water (Japan Sea Proper Water) (Itaki, 2003). For these modern distributions, the high abundance of *C. davisiana* in the sub-polar region is interpreted as a result of the intermediate water formation (Itaki et al., 2004). Therefore, our results suggest that the intermediate water formed by sea-ice development was widely distributed in the Southern Ocean.

The % of *C. davisiana* is relative value to the total radiolarian assemblage, whereas absolute abundance (# of specimens / gram of dry sediment weight) reflects their productivity in the water column. In core COR-1bPC, the absolute abundance of *C. davisiana* is characterized by high values greater than 5,000 specimens/g in the last glacial period during 37 kyr BP (kilo-years before present) to 12 kyr BP, and recognized a maximum exceeded 80,000 specimens/g at 17 kyr BP. Such fluctuation of the *C. davisiana* abundance shows synchrony with iron (Fe_2O_3) contents from the examined core. Generally, it is believed that the iron, which is a characteristic lithogenic component, is transported into the Southern Ocean from the land as aeolian dust or ice-rafted debris (IRD). However, maximum content of the iron in core COR-1bPC, which is recognized in the deglacial period, is too late than that expected in the last glacial maximum (LGM) because of the most expanded dust transportation and Antarctic ice-sheet. On the other hand, in the modern Sea of Okhotsk, it is known that the lithogenic and organic matters in the northern shelf region are transported into the intermediate layer with advection of the brine origin dense water (Nakatsuka et al., 2002). The *C. davisiana* productivity in the Sea of Okhotsk is closely related to such organic matter transported from the shelf region (Okazaki et al., 2003). If similar process can be applied to the case in the glacial Southern Ocean, synchronized maxima of the *C. davisiana* abundance and iron contents during the deglaciation are likely related to more expansion of the intermediate water originated from the Antarctic shelf region.

南大洋の海洋循環は，世界の気候変動に重要な役割を果たしている．南大洋において過去の海洋循環を復元する際には，堆積物中に豊富に保存されている珪質微化石の珪藻や放散虫が広く用いられている．植物プランクトンの珪藻は表層付近の環境を示すのに対し，動物プランクトンの放散虫は種により生息深度が異なるため，表層のみではなく中深層の環境指標ともなる．本研究では，南大洋インド洋セクターのコンラッド海堆で採取され

たコア COR-1bPC（54°S）とリュツォホルム湾沖のコア LHB-3PC（66°S）について放散虫の定量分析を行い，中層水の指標種である *Cycladophora davisiana* の産出頻度から過去の中層水形成について議論する．

両コアに含まれる *C. davisiana* の全放散虫群集に対する割合は，間氷期では数%程度しか含まないが，氷期の層準で 60%にも達する優占種となる．この様な *C. davisiana* の高い産出頻度は，現在のオホーツク海において認められ，海氷形成によって沈み込んだオホーツク海中層水に対応する水深 200～500m 付近に多く生息している（例えば，Okazaki et al., 2004）．また，日本海においても活発な沈み込みで形成された日本海固有水を特徴付ける群集を構成している（Itaki, 2003）．これらの現在の分布から，本種の産出頻度の増加は，海氷発達に伴う中層水形成の結果として解釈される（Itaki et al., 2004）．すなわち，氷期の南大洋には海氷発達に伴って形成された中層水が広く分布していたことを示唆している．

堆積物 1 g 中に含まれる *C. davisiana* の個体数は，%が全放散虫群集に対する相対的な割合を示すに対して，本種の生産量を反映している．コア COR-1bPC の記録を詳しく見ると，1.2～3.7 万年前は 5,000 個体/ g 以上の高い産出量で特徴付けられ，特に 1.7 万年前には 80,000 個体/ g を越す極大が認められる．これを同じコアから得られている化学組成データと比較すると，*C. davisiana* の個体数は，鉄（Fe_2O_3）の濃度と同調して変化していることが明らかとなった．南大洋における鉄は，風成塵や氷床などによって陸域から海域に供給される．しかし，コア COR-1bPC における鉄濃度の極大は，最終氷期から完新世にかけての退氷期に認められ，風成塵輸送や氷床が最も発達した最終氷期極相期よりも遅れている．一方，現在のオホーツク海では，ブラインを起源とした高密度水が大陸棚の陸源粒子と有機物を取り込んで中層に移入することが知られている（Nakatsuka et al., 2002）．また，オホーツク海での *C. davisiana* の生産量は，この陸棚から運ばれてきた有機物量と密接な関係がある（Okazaki et al., 2003）．これらの事実は，コア COR-1bPC で認められた *C. davisiana* 個体数と鉄濃度の増減が南極沿岸を起源とした中層水と関連し，特に融氷期にはこれが著しく発達していたことを示唆している．

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